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**Campbell**

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(54) **REAR COLLISION ALERT SYSTEM**

(71) Applicant: **Ambarella, Inc.**, Santa Clara, CA (US)

(72) Inventor: **Jeffery Campbell**, San Jose, CA (US)

(73) Assignee: **Ambarella, Inc.**, Santa Clara, CA (US)

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*B60Q 1/52* (2006.01)  
*B60Q 1/46* (2006.01)

(52) **U.S. Cl.**

CPC ..... *B60Q 1/525* (2013.01); *B60Q 1/46* (2013.01); *H04N 5/247* (2013.01)

(58) **Field of Classification Search**

None  
See application file for complete search history.

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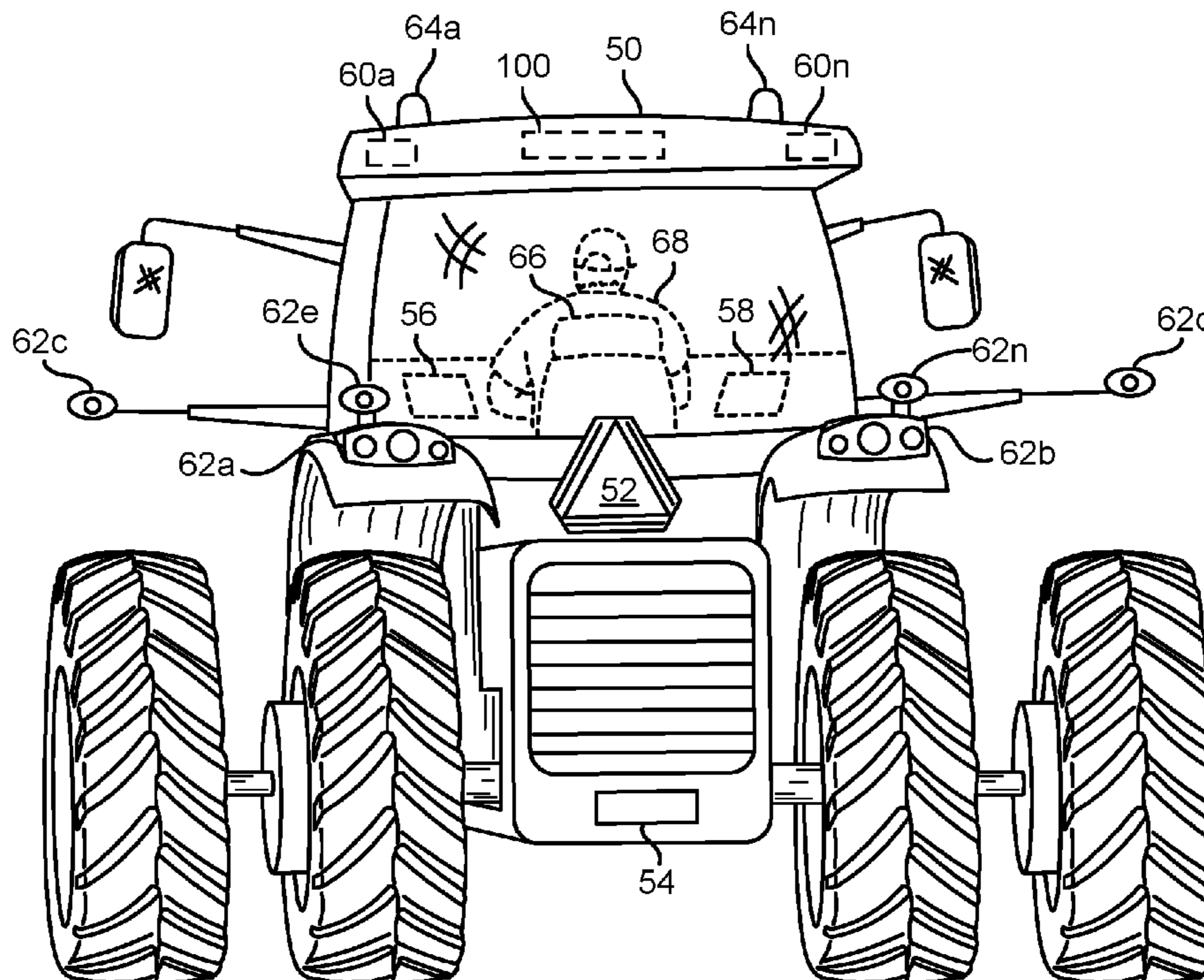
*Primary Examiner* — Eileen M Adams

(74) *Attorney, Agent, or Firm* — Christopher P. Maiorana, PC

(57) **ABSTRACT**

An apparatus comprising a sensor and a processor. The sensor may be configured to capture video frames of an environment near a vehicle. The processor may be configured to (i) receive the video frames from the sensor, (ii) perform video analytics on the video frames and (iii) generate a control signal in response to the video analytics. The video analytics may analyze visual content in the video frames to identify an object approaching the vehicle. The video analytics may determine an expected path of the object approaching the vehicle. The control signal may be configured to generate a warning for the object approaching the vehicle if the expected path poses a collision hazard with the vehicle.

**18 Claims, 8 Drawing Sheets**



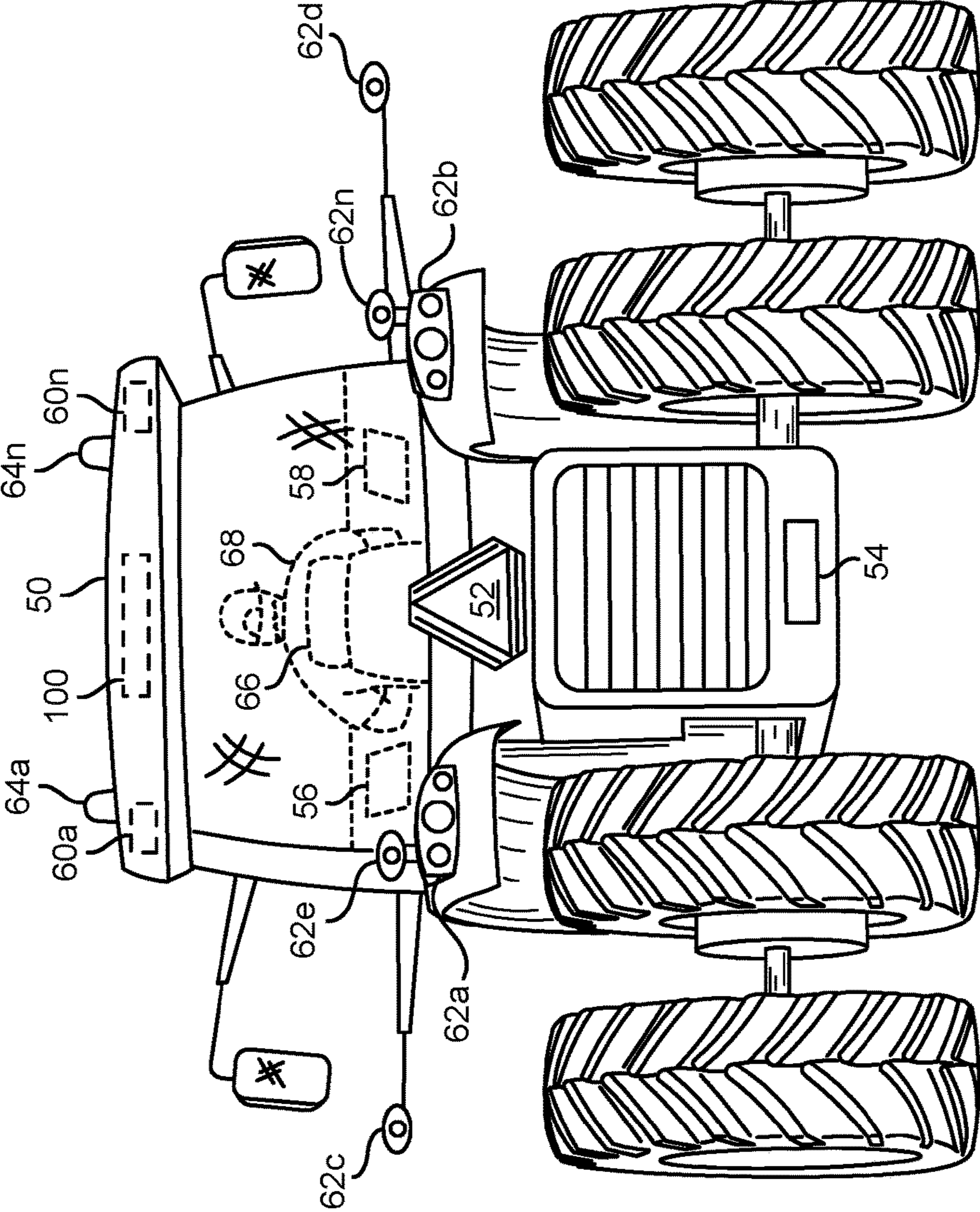
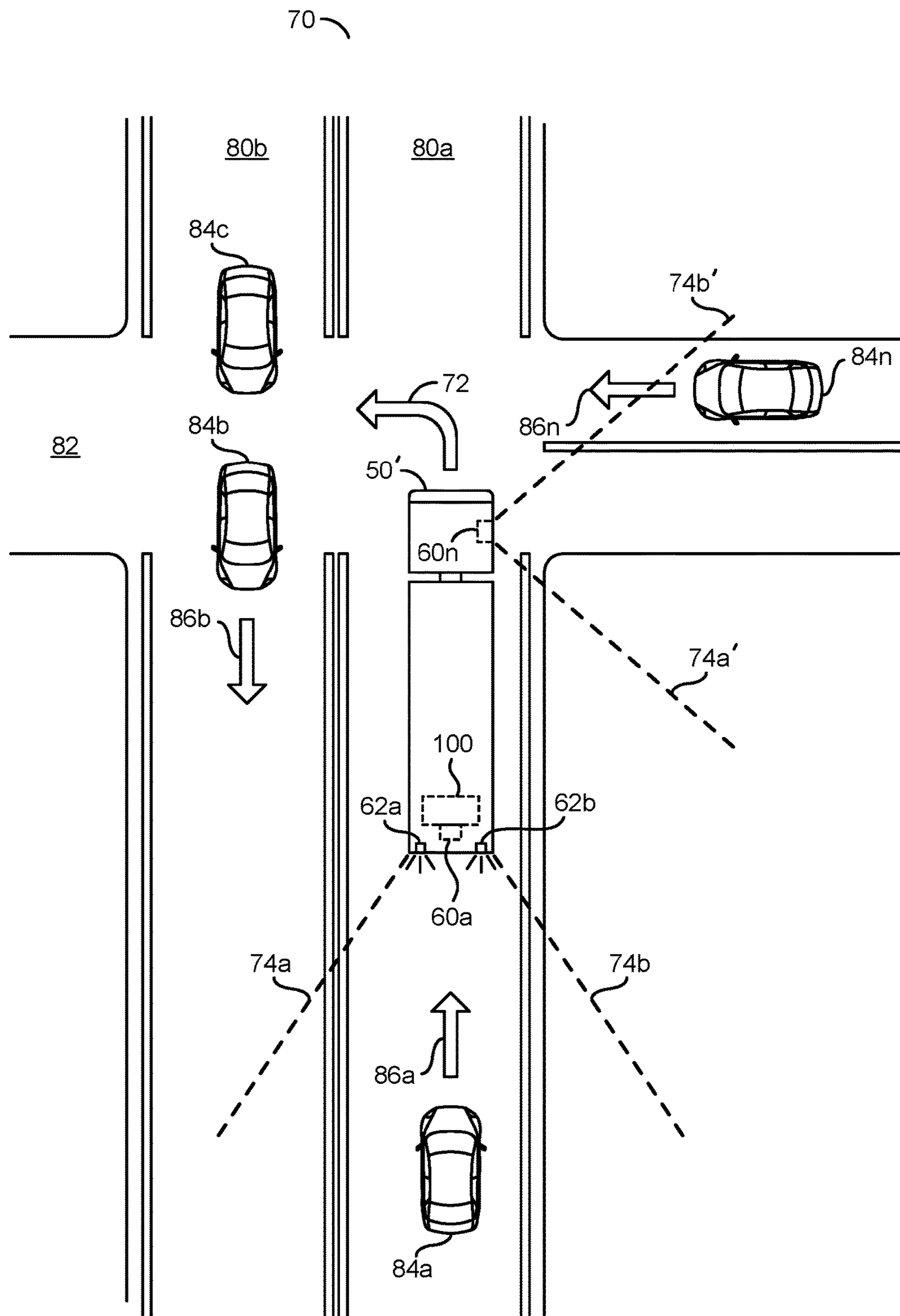
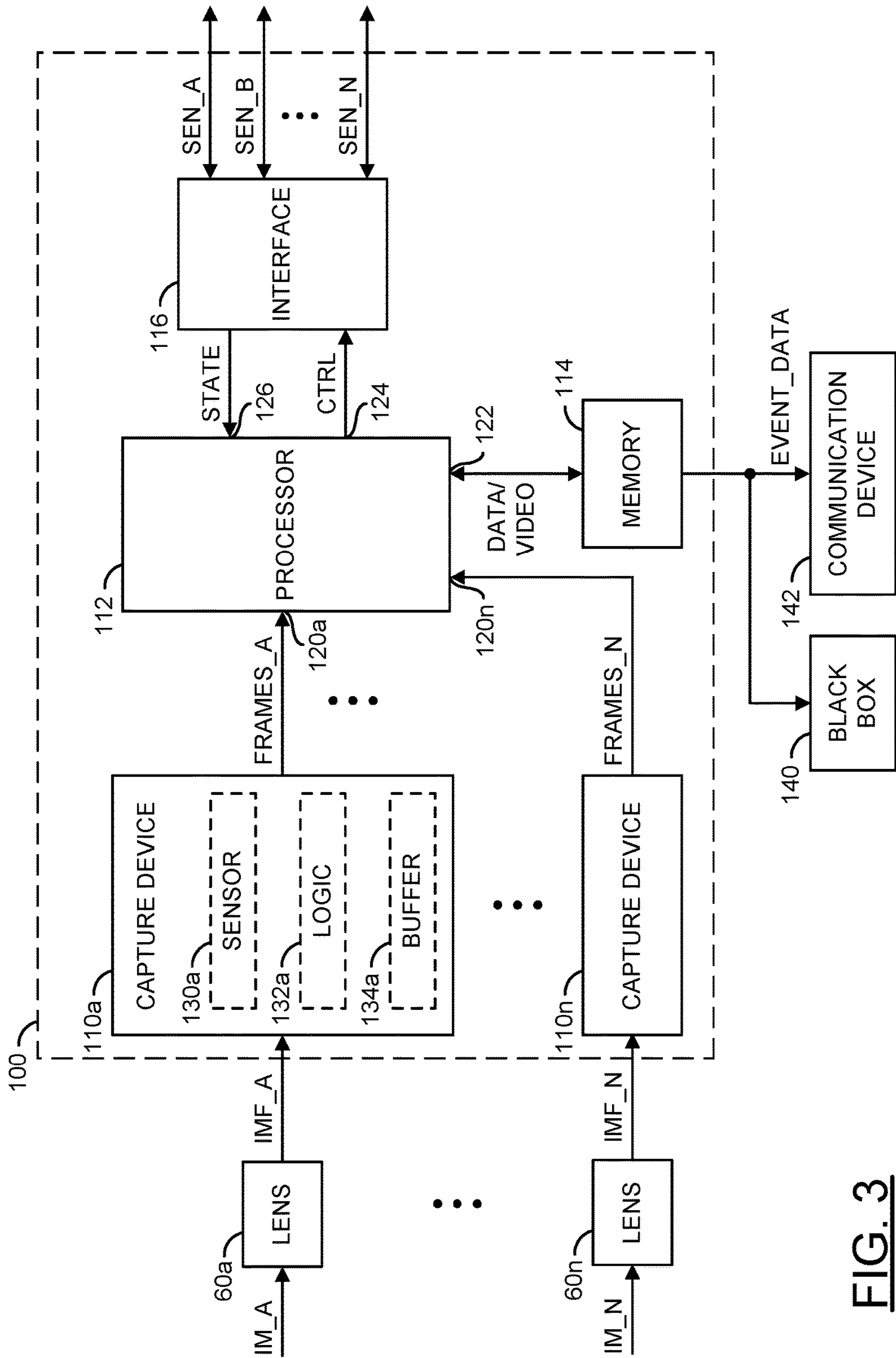


FIG. 1



**FIG. 2**





**FIG. 3**

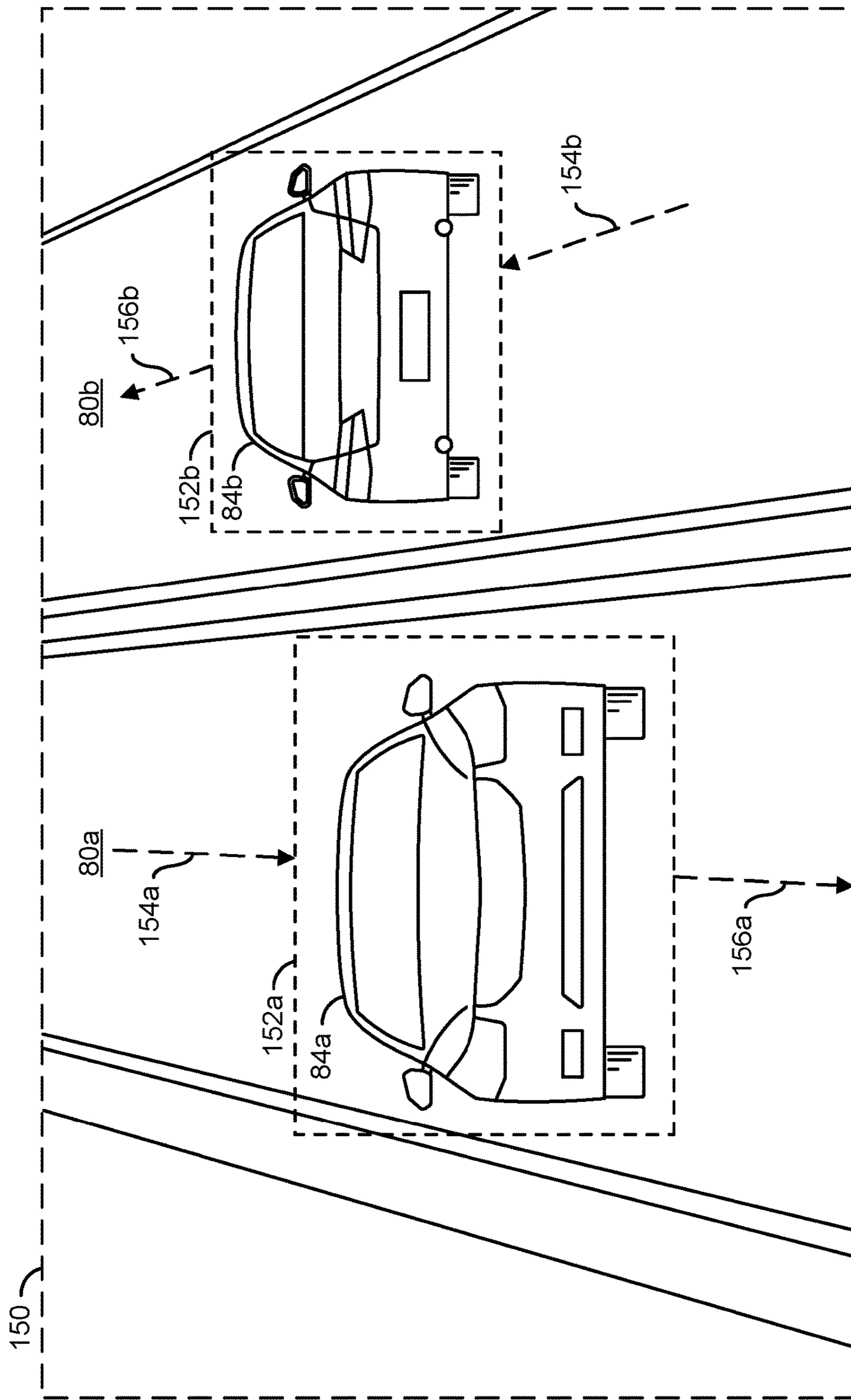


FIG. 4

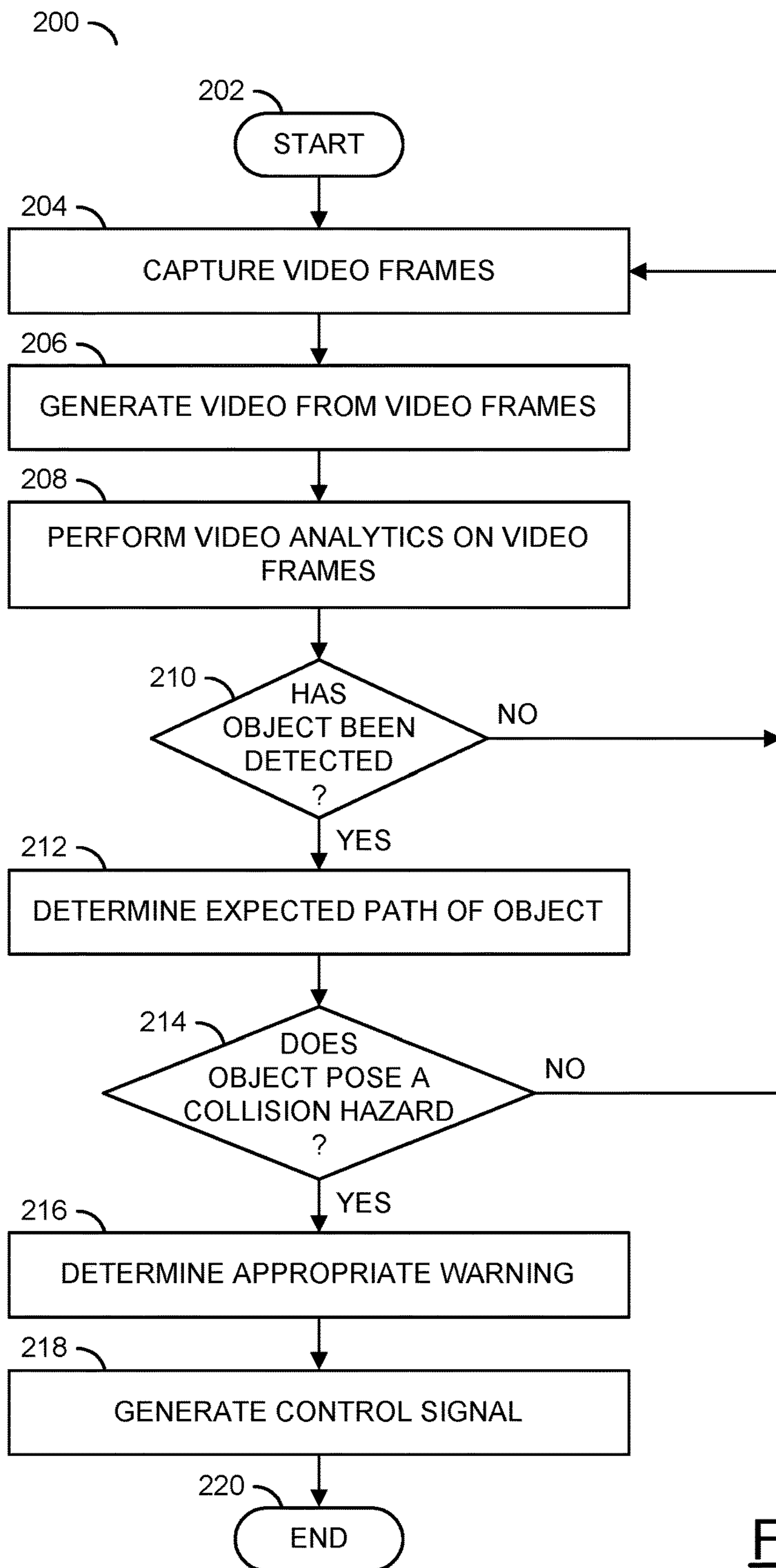
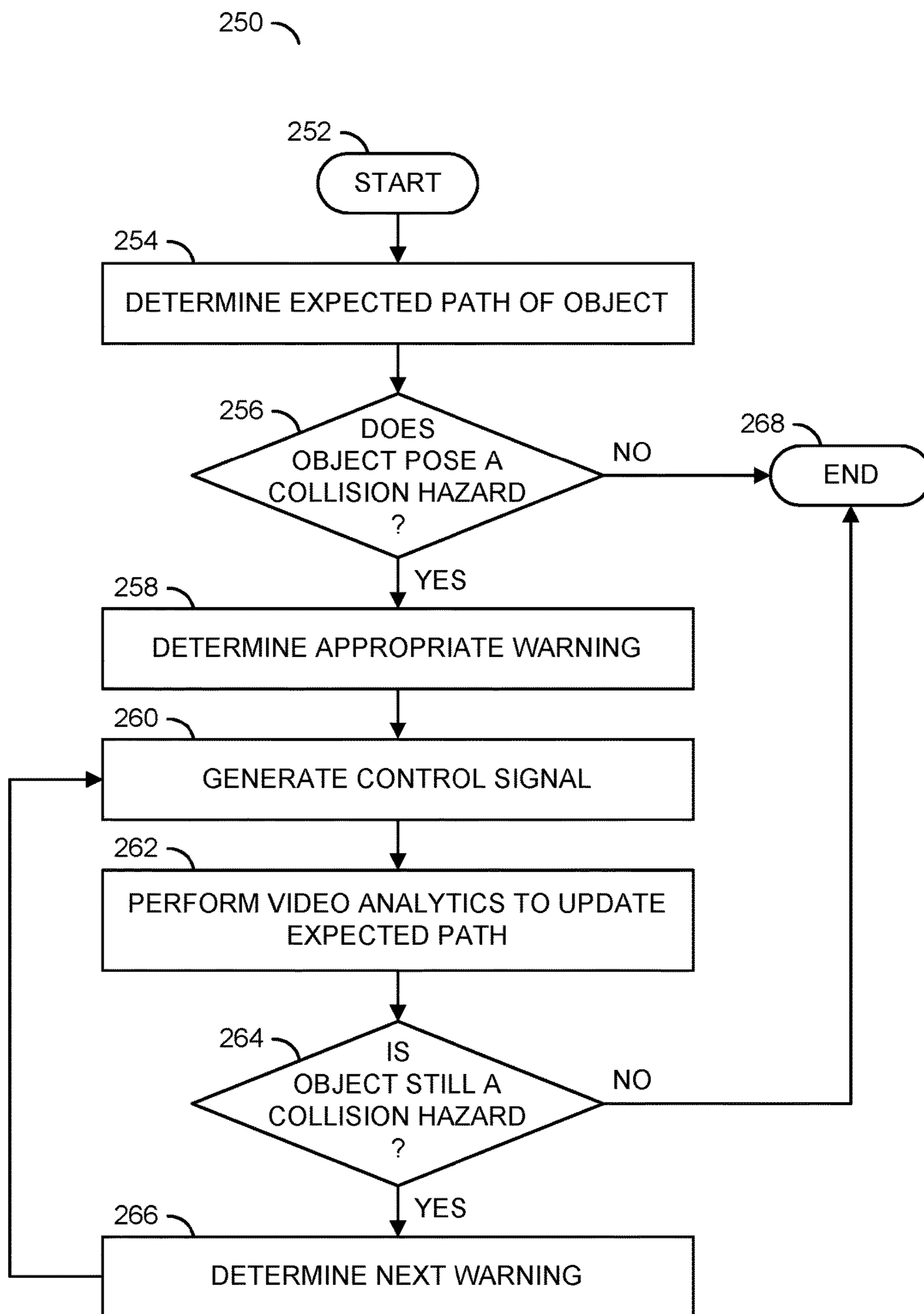


FIG. 5



**FIG. 6**

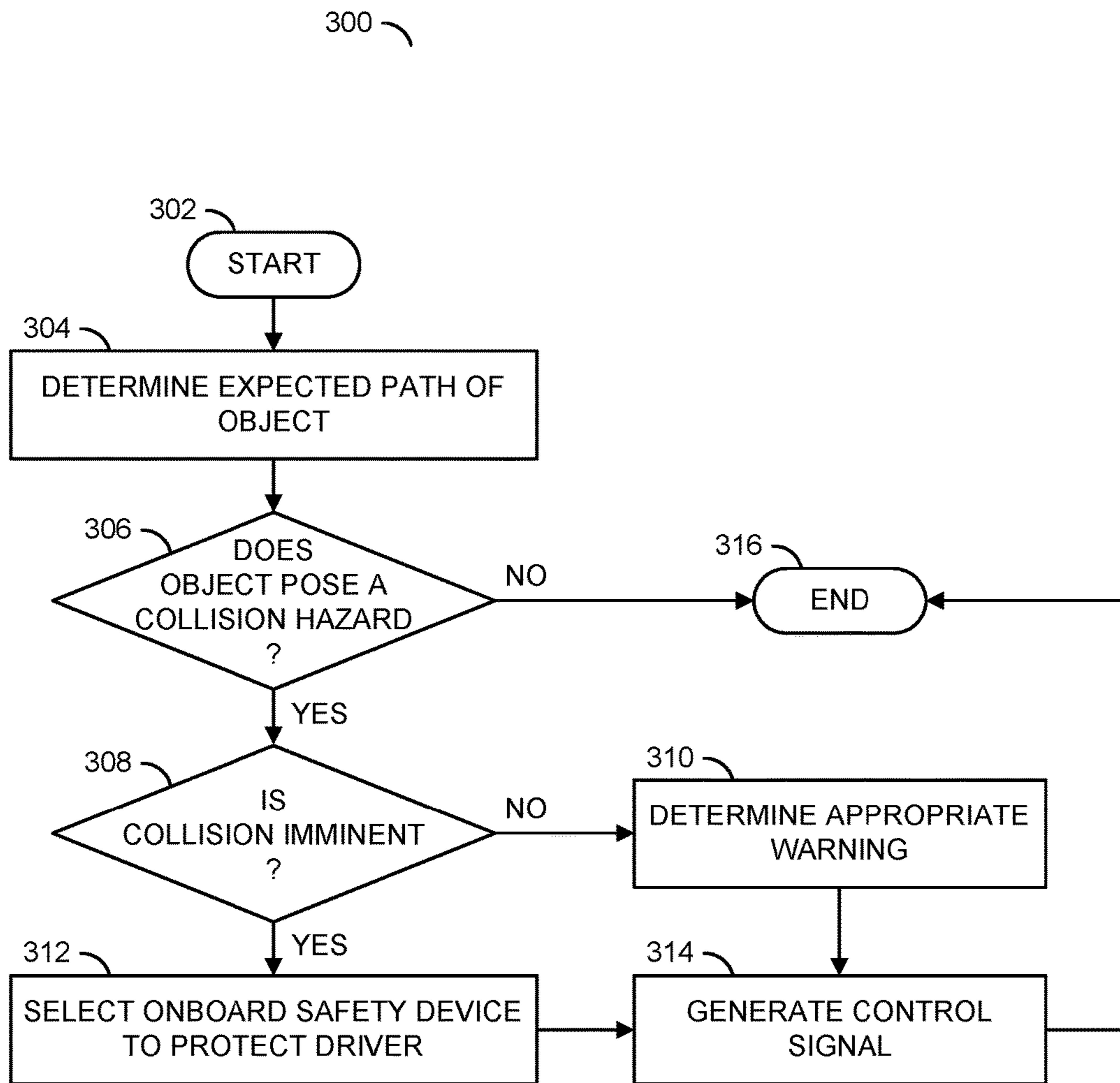
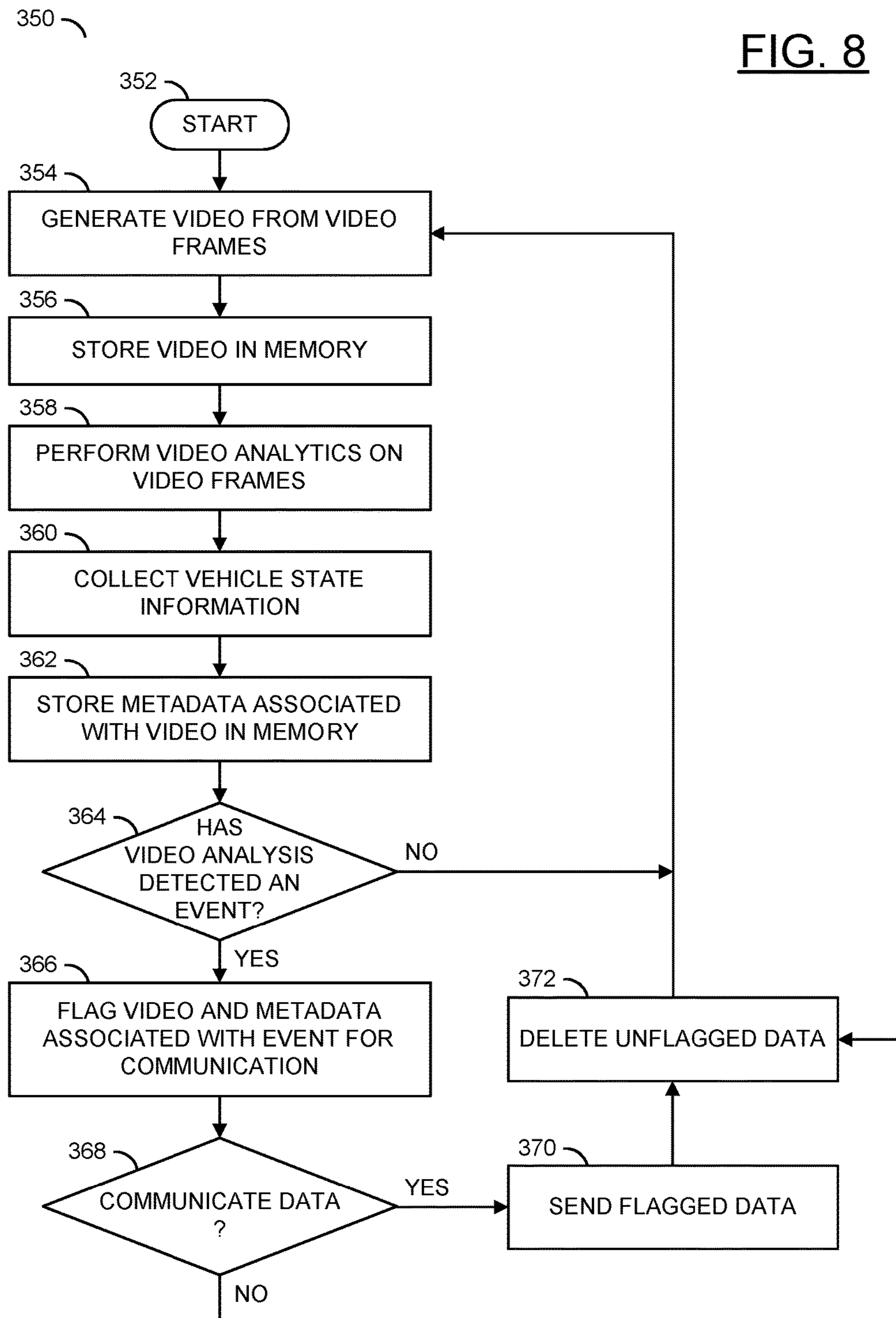


FIG. 7



FIG. 8



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## REAR COLLISION ALERT SYSTEM

## FIELD OF THE INVENTION

The invention relates to video capture generally and, more particularly, to a method and/or apparatus for implementing a rear collision alert system.

## BACKGROUND

Slow-moving or stationary vehicles on a roadway are at risk of being struck from behind when traffic conditions are such that other vehicles traveling in the same direction are moving at faster speeds. Drivers approaching a slow-moving or stationary vehicle might not expect to need to brake quickly, might misjudge speed differences, or might not notice the vehicle ahead. One common scenario is a night-time, left hand turn from a busy thoroughfare to a residential street where no traffic light is present. The left hand turn may be delayed by oncoming traffic and the vehicle may be stationary while waiting to turn. The stationary vehicle can be at risk of being struck by fast moving vehicles approaching from behind.

Experienced drivers might attempt to alert other drivers approaching from behind that the vehicle the driver is piloting has stopped or has reduced speed with a visual indication using brake lights located at the tail of the vehicle in front. One common practice for vigilant drivers is to “pump” or rapidly release and depress the brake pedal to toggle the tail brake lights and therefore make them more conspicuous to alert the driver of the oncoming vehicle to take action. However, in the left hand turn scenario, the driver of the stationary vehicle in front might not be aware of vehicles approaching from behind. Often drivers making a left hand turn are focused on the oncoming traffic in order to safely complete the turn.

It would be desirable to implement a rear collision alert system.

## SUMMARY

The invention concerns an apparatus comprising a sensor and a processor. The sensor may be configured to capture video frames of an environment near a vehicle. The processor may be configured to (i) receive the video frames from the sensor, (ii) perform video analytics on the video frames and (iii) generate a control signal in response to the video analytics. The video analytics may analyze visual content in the video frames to identify an object approaching the vehicle. The video analytics may determine an expected path of the object approaching the vehicle. The control signal may be configured to generate a warning for the object approaching the vehicle if the expected path poses a collision hazard with the vehicle.

## BRIEF DESCRIPTION OF THE FIGURES

Embodiments of the invention will be apparent from the following detailed description and the appended claims and drawings in which:

FIG. 1 is a diagram illustrating an example embodiment of the invention;

FIG. 2 is a diagram illustrating an example of a warning in a left hand turn scenario;

FIG. 3 is a block diagram illustrating an example embodiment of a system on chip for implementing a collision warning using video analytics;

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FIG. 4 is a diagram illustrating an example video frame analyzed using video analytics;

FIG. 5 is a flow diagram illustrating a method for generating a control signal in response to a detected object posing a collision hazard;

FIG. 6 is a flow diagram illustrating a method for implementing multiple warning types;

FIG. 7 is a flow diagram illustrating a method for activating safety measures in response to an imminent collision; and

FIG. 8 is a flow diagram illustrating a method for collecting and communicating safety data using video analytics.

## DETAILED DESCRIPTION OF THE EMBODIMENTS

Embodiments of the present invention include providing a rear collision alert system that may (i) prevent collisions, (ii) warn other drivers of a slow-moving and/or stationary vehicle, (iii) interface with components of a vehicle to generate a warning, (iv) alert a driver of an imminent collision, (v) implement video analytics to determine an expected path of oncoming vehicles and/or (vi) be implemented as one or more integrated circuits.

Referring to FIG. 1, a diagram illustrating an example embodiment of the invention is shown. An apparatus 100 is shown. The apparatus 100 may be implemented in (or on) a vehicle 50. The vehicle 50 may be a slow-moving vehicle and/or a stationary vehicle. In the example shown, the vehicle 50 may be a tractor. The vehicle 50 is shown displaying the slow-moving vehicle sign 52. In another example, the slow-moving may be traveling at a speed in accordance with posted speed limits and another vehicle may be speeding (e.g., the vehicle 50 is traveling at a normal speed, but is slow-moving with respect to another vehicle).

The vehicle 50 may implement various components. The apparatus 100 may be configured to interface and/or communicate with the various components of the vehicle 50. The various components of the vehicle 50 may comprise a block (or circuit) 54, an onboard safety component 56, a block (or circuit) 58, a blocks (or circuits) 60a-60n, tail lights 62a-62n, warning lights 64a-64n and/or a seat 66. A driver 68 of the vehicle 50 is shown in the seat 66. The number and/or types of components of the vehicle 50 may be varied according to the design criteria of a particular implementation.

The circuit 54 may be an audio output device. In one example, the audio output device 54 may be a speaker located on an exterior of the vehicle 50. In the example shown, the audio output device 54 may be directed towards a rear of the vehicle 50. In another example, the audio output device 54 may be a horn of the vehicle 50. The audio output device 54 may be configured to generate audio. The audio generated by the audio output device 54 may be implemented as a warning to other drivers and/or pedestrians. For example, the audio output device 54 may be configured to alert others of the presence of the vehicle 50. The location, implementation, audio level and/or tone of the audio output device 54 may be varied according to the design criteria of a particular implementation.

The onboard safety component 56 is shown as a representative example for various onboard safety components implemented by the vehicle 50. In one example, the onboard safety component 56 may be an airbag system. In another example, the onboard safety component 56 may be a seatbelt restraint system. In yet another example, the onboard safety



component **56** may be a driver assistance module configured to autonomously perform evasive driving maneuvers. The implementation of the onboard safety component **56** may be varied according to the design criteria of a particular implementation.

The circuit **58** may be configured as a display device. In one example, the display device may be a LCD (or LED or OLED) screen. In another example, the display device may be a touchscreen display. The display device **58** may be the infotainment unit of the vehicle **50**. The display device **58** may be configured to display images and/or video to the driver **68**.

The circuits **60a-60n** may be configured as cameras and/or camera lenses. The camera lenses **60a-60n** may be directed to capture images of the environment near the vehicle **50**. In one example, the lens **60a** may be implemented as a rear-facing camera lens directed to capture a view to the rear of the vehicle **50**. In some embodiments, the lenses **60a-60n** may be a component of the vehicle **50** (e.g., a back-up camera). In some embodiments, the lenses **60a-60n** may be installed as an after-market part for the vehicle **50** (e.g., a dashboard camera). In some embodiments, the lenses **60a-60n** may be implemented as one or more wide angle (or fisheye) lenses. In some embodiments, the lenses **60a-60n** may be implemented as components of a multi-sensor camera. The number, type, direction and/or location of the lenses **60a-60n** may be varied according to the design criteria of a particular implementation.

The tail lights **62a-62n** may be configured to emit light from the rear of the vehicle **50**. The tail lights **62a-62n** may be implemented as braking lights to warn drivers behind the vehicle **50** that the vehicle **50** has applied the brakes (e.g., is slowing down and/or stopping). The tail lights **62a-62n** may be toggled on/off (e.g., pulsed) to implement turn signals. Generally, the tail lights **62a-62n** may be implemented to provide a warning to drivers behind the vehicle **50**. For example, the tail lights **62a-62n** may make the vehicle **50** more visible (e.g., at night, in heavy rain, when snow is falling and/or in foggy conditions).

The warning lights **64a-64n** are shown on the roof of the vehicle **50**. The warning lights **64a-64n** may be implemented as colored and/or strobe lights. In some embodiments, the warning lights **64a-64n** may be police lights and/or emergency vehicle (e.g., ambulance, fire truck, etc.) lights. Generally, the warning lights **64a-64n** may be implemented to warn other drivers and/or pedestrians of the vehicle **50**.

The seat **66** may be an illustrative example of a component of the vehicle **50** configured to provide haptic feedback. For example, the seat **66** may be configured to vibrate to provide feedback to the driver **68**. Other components of the vehicle **50** may be configured to provide haptic feedback. In one example, the steering wheel may provide haptic feedback to the hands of the driver **68**.

The apparatus **100** may be configured to receive video frames from one or more of the lenses (or cameras) **60a-60n**. The lenses **60a-60n** may be configured to capture the environment near the vehicle **50**. The apparatus **100** may be configured to implement a rear collision alert system. To generate rear collision alerts, the environment near the vehicle **50** may be monitored by the apparatus **100**. In one example, the lenses **60a-60n** may be rear facing camera(s) placed at the rear of the vehicle **50** to monitor the environment to the rear of the vehicle **50**.

In some embodiments, the apparatus **100** may be a component of a camera. In some embodiments, the apparatus **100** may be a component of the vehicle **50**. The apparatus **100** may be a processor and/or a system on chip (SoC). For

example, the apparatus **100** may be implemented as a printed circuit board comprising one or more components. The apparatus **100** may be configured to encode video frames captured by sensors receiving light from the lenses **60a-60n**.

In some embodiments, the apparatus **100** may be configured to perform video stitching operations to stitch video frames captured by each of the lenses **60a-60n** to capture a wide angle view and/or a multi-camera view. In some embodiments, the apparatus **100** may be configured to perform de-warping operations to correct distortion of the video frames caused by the lenses **60a-60n**. The apparatus **100** may format (or encode, or compress, or crop) the video signals to enable wireless transmission, output to the display device **58** and/or local storage of video data.

The apparatus **100** may be configured to identify other vehicles approaching the vehicle **50** from behind that pose a risk of colliding into the tail (e.g., rear) of the vehicle **50** in front. The camera(s) comprising the lenses **60a-60n** may feed visual data to a connected and/or embedded processor (e.g., to be described in more detail in association with FIG. **3**). The processor of the apparatus **100** may be configured to perform video analytics on the video frames. The video analytics may detect (or identify or recognize) objects in the video frames. In an example, the apparatus **100** may implement the video analytics to calculate the speed of the incoming object and/or rate of decrease in speed (if any). The apparatus **100** may be configured to determine an expected path of the object and/or whether the object poses a collision hazard.

The apparatus **100** may be configured to generate a control signal. The control signal may be configured to generate a warning for the detected object. Generally, the warning may be implemented to alert a driver of an incoming vehicle about a potential collision with the vehicle **50**. The warning generated in response to the control signal may be implemented by one or more components of the vehicle **50**. In one example, the control signal may activate the brake tail light system (e.g., the lights **62a-62n**) to flash (or blink) as the warning. The blinking brake lights **62a-62n** may warn the driver approaching the vehicle **50** of a potential collision.

The apparatus **100** may be augmented using various components of the vehicle **50** and/or other add-on components (e.g., after-market components). In one example, the components of the vehicle **50** may be the additional lights **64a-64b** (e.g., lights other than the brake lights **62a-62n**) that target the incoming driver to alert of an impending collision. The components of the vehicle **50** may comprise the audio output device **54**. For example, the audio output device **54** may be integrated as a rear directed speaker that may be activated as an alert. Generally, the components of the vehicle **50** may be used as the warning to motivate the incoming driver to engage a braking system and/or take some other corrective action.

The apparatus **100** may be configured to alert the driver **68** of the vehicle **50** under threat of a collision. In one example, the apparatus **100** may be configured to generate an alert using a visual cue. The visual cue may be output to the display **58** (e.g., to alert the driver **68**). In another example, the apparatus **100** may be configured to generate an alert using an auditory cue. The auditory cue may be output using the vehicle audio system (e.g., the radio, the infotainment system, etc.). In yet another example, the apparatus **100** may be configured to generate an alert using a haptic cue. The haptic cue may be a vibration of the car seat **66**.

The alert may be implemented to provide the driver **68** with a warning to take evasive action to avoid an impact. In one example, the driver may attempt an evasive maneuver



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using the vehicle **50**. In another example, the vehicle **50** may be too slow to perform an evasive maneuver and the evasive action taken by the driver **68** may be to escape the vehicle **50**. In yet another example, if the vehicle **50** is configured to drive autonomously, the alert by the apparatus **100** may be configured to initiate autonomous driving to avoid the collision.

The apparatus **100** may be configured to present the control signal to activate and/or initiate onboard safety devices **56** implemented by the vehicle **50**. In one example, the onboard safety devices **56** may comprise an airbag. In another example, the onboard safety devices **56** may comprise a seat belt restraint system. When the apparatus **100** determines that an impact may be imminent, the apparatus **100** may generate the control signal to activate and/or initiate one or more of the onboard safety devices **56**. For example, by initiating the onboard safety devices **56**, the safety features implemented may be enhanced and/or augmented (e.g., providing additional activation time).

Referring to FIG. 2, a diagram illustrating an example of a warning in a left hand turn scenario **70** is shown. In the left hand turn scenario **70**, the slow-moving vehicle **50'** is shown as a transport truck. In the left hand turn scenario **70**, the vehicle **50'** may be waiting to make a left hand turn **72**. The apparatus **100** may be implemented in the vehicle **50'**. The lens **60a** and the lens **60n** are shown on the vehicle **50'**. The tail lights **62a-62b** are shown emitting light indicating that the brakes are being held as the vehicle **50'** waits to make a turn. Lines **74a-74b** may represent a field of view of the lens **60a**. Lines **74a'-74b'** may represent a field of view of the lens **60n**. For example, one or more of the lenses **60a-60n** may be capturing the environment near the vehicle **50'**. The field of view **74a-74b** and/or the field of view **74a'-74b'** may be the environment captured by one or more of the lenses **60a-60n**.

The example left hand turn scenario **70** may comprise a lane **80a** and an oncoming lane **80b**. An intersecting road **82** may intersect with the lanes **80a-80b**. For example, the lanes **80a-80b** may be the lanes of a higher traffic road, and the intersecting road **82** may be a lower traffic (e.g., residential) road. Vehicles **84a-84n** may be driving in the lanes **80a-80b** and/or the intersecting road **82**. Arrows **86a-86n** are shown to indicate a direction of travel for the respective vehicles **84a-84n**.

In the example left hand turn scenario **70**, the vehicle **50'** may be stopped in the lane **80a**, waiting to make the left hand turn **72** onto the intersecting road **82**. The vehicles **84b-84c** are shown in the oncoming lane **80b** traveling in the direction **86b**. For example, the vehicle **50'** may be blocked from making the left hand turn **72** onto the intersecting road **82** by the vehicles **84b-84c**. The vehicle **84a** may be in the lane **80a**. The vehicle **84a** is shown traveling behind the vehicle **50'** and in the direction **86a** (e.g., approaching the vehicle **50'** from behind). For example, the vehicle **84a** may be a vehicle approaching the vehicle **50'** from the rear. The approaching vehicle **84a** may need to stop, slow down and/or move around the vehicle **50'** to avoid a collision with the vehicle **50'**.

In the example left hand turn scenario **70**, the approaching vehicle **84a** may be within the field of view **74a-74b** of one or more of the camera lenses **60a-60n**. The apparatus **100** may perform the video analytics to determine the expected path of the approaching vehicle **84a**. If the approaching vehicle **84a** poses a collision hazard, the apparatus **100** may generate a control signal. For example, the control signal may activate and/or blink the tail lights **62a-62b**. The blinking tail lights **62a-62b** may be the warning for the vehicle **84a** behind the vehicle **50'**.

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Similarly, the apparatus **100** may be configured to detect collision hazards to a side and/or front of the vehicle **50'**. In the example shown, the lens **60n** is shown capturing the environment (e.g., the field of view **74a'-74b'**) on the passenger side of the vehicle **50'**. The vehicle **84n** is shown on the intersecting road **82** traveling towards the intersection in the direction **86n**. In an example, the intersecting road **82** may have a stoplight at the intersection with the lanes **80a-80b**. If the driver of the vehicle **84n** does not stop at the intersection (e.g., during a red stoplight), the vehicle **84n** may pose a side-collision (e.g., a T-bone collision) hazard with the vehicle **50'** (e.g., the vehicle **50'** may have a green stoplight). The vehicle **84n** may be within the field of view **74a'-74b'** of one or more of the camera lenses **60a-60n**. The apparatus **100** may perform the video analytics to determine the expected path of the vehicle **84n**. If the vehicle **84n** poses a collision hazard, the apparatus **100** may generate the control signal. For example, the control signal may activate the audio output device **54** to alert the driver of the vehicle **84n**. In another example, the control signal may display a warning to the driver **68** to stop entering the intersection to avoid the potential collision with the vehicle **84n**.

Referring to FIG. 3, a block diagram illustrating an example embodiment of the apparatus **100** for implementing a collision warning using video analytics is shown. The apparatus **100** generally comprises blocks (or circuits) **110a-110n**, a block (or circuit) **112**, a block (or circuit) **114** and/or a block (or circuit) **116**. The circuits **110a-110n** may be implemented as capture devices. The circuit **112** may be implemented as a processor. In an example implementation, the circuit **112** may be implemented as a video processor. The processor **112** may comprise inputs **120a-120n**, an input **122**, an input **126** and/or other inputs. The processor **112** may comprise an output **124** and/or other outputs. The circuit **114** may be implemented as a memory. The circuit **116** may be implemented as an interface. The apparatus **100** may comprise other components (not shown). The apparatus **100** may be implemented as a system on chip.

The apparatus **100** may implement a camera system. In some embodiments, the camera system **100** may be implemented as a drop-in solution (e.g., installed as one component). In an example, the camera system **100** may be a device that may be installed as an after-market product for the vehicle **50** (e.g., a retro-fit for the vehicle **50**). In some embodiments, the apparatus **100** may be a component of a camera. The number and/or types of signals and/or components implemented by the camera system **100** may be varied according to the design criteria of a particular implementation.

In the embodiment shown, the apparatus **100** is shown connected to a block (or circuit) **140** and/or a block (or circuit) **142**. The circuit **140** may be a black box recorder. The circuit **142** may be a communication device. The black box recorder **140** may be configured to preserve a recent history of the components of the vehicle **50** through the recording of various parameters (e.g., collected several times per second). The black box recorder **140** may be configured to survive accidents and/or collisions. The black box recorder **140** may be implemented to preserve data for assisting in an investigation. The communication device **142** may be configured to enable communication with components outside of the vehicle **50**.

In the embodiment shown, the capture devices **110a-110n** may be components of the apparatus **100**. In some embodiments, the capture devices **110a-110n** may be separate devices (e.g., part of the vehicle **50** and/or part of a camera) configured to send data to the apparatus **100**. Similarly, in



some embodiments, the interface **116** may be implemented as a component external to the apparatus **100**. For example, the interface **116** may be a component of the vehicle **50**. In some embodiments, the apparatus **100** may be configured to read data in a format generated by the capture devices **110a-110n**. In some embodiments, the processor **112** may be configured to generate a signal compatible with the interface **116**. Similarly, in the example shown, the black box recorder **140** and the communication device **142** are shown as components external to the apparatus **100**. However, in some embodiments, the black box recorder **140** and/or the communication device **142** may be implemented as components of the apparatus **100**.

The apparatus **100** may receive one or more signals (e.g., IMF\_A-IMF\_N). The apparatus **100** may present one or more signals (e.g., SEN\_A-SEN\_N). The apparatus may present a signal (e.g., EVENT\_DATA). The capture devices **110a-110n** may receive the signals IMF\_A-IMF\_N from the corresponding lenses **60a-60n**. The apparatus **100** may present one or more of the signals SEN\_A-SEN\_N to various components of the vehicle **50** (e.g., to generate the warning of the potential collision hazard). In some embodiments, the apparatus **100** may present the signal EVENT\_DATA to the wireless communication device **142** (e.g., a radio-frequency (RF) transmitter, a Wi-Fi module, Bluetooth module and/or a device capable of other wireless communication protocols).

The lenses **60a-60n** may capture signals (e.g., IM\_A-IM\_N). The signals IM\_A-IM\_N may be an image (e.g., an analog image) of the environment near (e.g., behind) the vehicle **50** (e.g., within the field of view **74a-74b**) presented by the lenses **60a-60n** to the capture devices **110a-110n** as the signals IMF\_A-IMF\_N. The lenses **60a-60n** may be implemented as an optical lens. The lenses **60a-60n** may provide a zooming feature and/or a focusing feature. The capture devices **110a-110n** and/or the lenses **60a-60n** may be implemented, in one example, as a single lens assembly. In another example, the lenses **60a-60n** may be a separate implementation from the capture devices **110a-110n**. The capture devices **110a-110n** are shown within the circuit **100**. In an example implementation, the capture devices **110a-110n** may be implemented outside of the circuit **100** (e.g., along with the lenses **60a-60n** as part of a lens/capture device assembly separate from the apparatus **100**).

The capture devices **110a-110n** may be configured to capture image data for video (e.g., the signals IMF\_A-IMF\_N from the lenses **60a-60n**). In some embodiments, the capture devices **110a-110n** may be video capturing devices such as cameras. In some embodiments, the apparatus **100** may implement a single lens assembly (e.g., one lens **60a** and one capture device **110a**). The capture devices **110a-110n** may capture data received through the lenses **60a-60n** to generate bitstreams (e.g., generate video frames). For example, the capture devices **110a-110n** may receive focused light from the lenses **60a-60n**. The lenses **60a-60n** may be directed, tilted, panned, zoomed and/or rotated to provide a targeted view from the vehicle **50** (e.g., to provide coverage for a view directed towards the rear of the vehicle). The capture devices **110a-110n** may generate signals (e.g., FRAMES\_A-FRAMES\_N). The signals FRAMES\_A-FRAMES\_N may be video data (e.g., a sequence of video frames). The signals FRAMES\_A-FRAMES\_N may be presented to the inputs **120a-120n** of the processor **112**.

The capture devices **110a-110n** may transform the received focused light signals IMF\_A-IMF\_N into digital data (e.g., bitstreams). In some embodiments, the capture devices **110a-110n** may perform an analog to digital con-

version. For example, the capture devices **110a-110n** may perform a photoelectric conversion of the focused light received by the lenses **60a-60n**. The capture devices **110a-110n** may transform the bitstreams into video data, video files and/or video frames. In some embodiments, the video data generated by the capture devices **110a-110n** may be uncompressed and/or raw data generated in response to the focused light from the lenses **60a-60n**. In some embodiments, the video data may be digital video signals. The video signals may comprise video frames.

In some embodiments, the video data may be encoded at a high bitrate. For example, the signal may be generated using a lossless compression and/or with a low amount of lossiness. In some embodiments, the video data captured by the capture devices **110a-110n** may be presented to the apparatus **100**. The apparatus **100** may encode the video data captured by the capture devices **110a-110n** to generate video data that may be output as a video signal (e.g., for the display device **58**) and/or may be in a format compatible with performing video analytics.

In some embodiments, the apparatus **100** may further comprise an audio capture device (e.g., a microphone). The audio capture device may capture audio of the environment. The apparatus **100** may be configured to synchronize the audio captured with the images captured by the capture devices **110a-110n**.

The processor **112** may receive the signals FRAMES\_A-FRAMES\_N from the capture devices **110a-110n** at the inputs **120a-120n** and/or a signal (e.g., DATA) from the memory **114** at the input **122**. The processor **112** may be connected through a bi-directional interface (or connection) to components of the vehicle **50**, the capture devices **110a-110n**, the memory **114** and/or the interface **116**. The processor **112** may store and/or retrieve data from the memory **114**. The memory **114** may be configured to store computer readable/executable instructions (or firmware). The instructions, when executed by the processor **112** may perform a number of steps.

The processor **112** may be configured to receive the signals FRAMES\_A-FRAMES\_N, the signal DATA, and/or other inputs. The signal FRAMES\_A-FRAMES\_N may comprise video data (e.g., one or more video frames) providing the field of view **74a-74b** captured by the lenses **60a-60n**. The processor **112** may be configured to generate an output video signal and/or other signals (not shown). The output video signal may be generated based on one or more decisions made and/or functions performed by the processor **112**. The decisions made and/or functions performed by the processor **112** may be determined based on data received by the processor **112** at the inputs **120a-120n** (e.g., the signals FRAMES\_A-FRAMES\_N), the input **122**, the input **126** and/or other inputs.

The inputs **120a-120n**, the input **122**, the output **124**, the input **126** and/or other inputs/outputs may implement an interface. The interface may be implemented to transfer data to/from the processor **112**, the capture devices **110a-110n**, the memory **114**, the interface **116** and/or other components of the apparatus **100** and/or the vehicle **50**. In one example, the interface of the processor **112** may be configured to receive (e.g., via the inputs **120a-120n**) the video streams FRAMES\_A-FRAMES\_N each from a respective one of the capture devices **110a-110n**. In yet another example, the interface of the processor **112** may be configured to output one or more upcoming video frames (e.g., the output video) to the display device **58** and/or to the memory **114** (e.g., as the signal DATA). The interface of the processor **112** may be configured to enable a transfer of data and/or translation of



data from one format to another format to ensure that the data transferred is readable by the intended destination component. In an example, the interface of the processor **112** may comprise a data bus, traces, connectors, wires and/or pins. The implementation of the interface of the processor **112** may be varied according to the design criteria of a particular implementation.

The output video may be presented to the memory **114** as the signal DATA. The output video may be an encoded, cropped, stitched and/or enhanced version of one or more of the signals FRAMES\_A-FRAMES\_N. The output video may be a high resolution, digital, encoded, de-warped, stabilized, cropped, blended, stitched and/or rolling shutter effect corrected version of the signals FRAMES\_A-FRAMES\_N. In some embodiments, the apparatus **100** may be configured to balance an amount of time needed to generate the output video with the visual quality of the output video. The signal DATA may further comprise metadata associated with the output video signal (e.g., a location, a timestamp, a severity of the collision hazard, a speed of the vehicles in the video, an acceleration of the vehicles in the video, etc.). The type and/or amount of the metadata in the signal DATA may be varied according to the design criteria of a particular implementation.

The video data of the targeted view from the perspective of the rear of the vehicle **50** may be represented as the signals/bitstreams/data FRAMES\_A-FRAMES\_N (e.g., video signals). The capture devices **110a-110n** may present the signals FRAMES\_A-FRAMES\_N to the inputs **120a-120n** of the processor **112**. The signals FRAMES\_A-FRAMES\_N may represent the video frames/video data. The signals FRAMES\_A-FRAMES\_N may be video streams captured by the capture devices **110a-110n**. In some embodiments, the capture devices **110a-110n** may be implemented in a camera. In some embodiments, the capture devices **110a-110n** may be configured to add to existing functionality to a camera.

Each of the capture devices **110a-110n** may comprise a block (or circuit) **130**, a block (or circuit) **132**, and/or a block (or circuit) **134**. The circuit **130** may implement a camera sensor (e.g., a complementary metal-oxide-semiconductor (CMOS) sensor). The circuit **132** may implement a camera processor/logic. The circuit **134** may implement a memory buffer. As a representative example, the capture device **110a** is shown comprising the sensor **130a**, the logic block **132a** and the buffer **134a**. The camera sensors **130a-130n** may receive light from the corresponding one of the lenses **60a-60n** and transform the light into digital data (e.g., the bitstreams).

In one example, the sensor **130a** of the capture device **110a** may receive light from the lens **60a**. The camera sensor **130a** of the capture device **110a** may perform a photoelectric conversion of the light from the lens **60a**. In some embodiments, the sensor **130a** may be an oversampled binary image sensor. The logic **132a** may transform the bitstream into a human-legible content (e.g., video data with visual content). The video analytics implemented by the processor **112** may be performed on the video data in a format that is human-legible (e.g., the visual content of the video data). For example, the logic **132a** may receive pure (e.g., raw) data from the camera sensor **130a** and generate video data based on the raw data (e.g., the bitstream). The memory buffer **134a** may store the raw data and/or the processed bitstream. For example, the frame memory and/or buffer **134a** may store (e.g., provide temporary storage and/or cache) one or more of the video frames (e.g., the video signal).

The processor **112** may be configured to execute computer readable code and/or process information. The processor **112** may be configured to receive input and/or present output to the memory **114** and/or the interface **116**. The processor **112** may be configured to present and/or receive other signals (not shown). The number and/or types of inputs and/or outputs of the processor **112** may be varied according to the design criteria of a particular implementation.

The processor **112** may receive the signals FRAMES\_A-FRAMES\_N and/or the signal DATA. The processor **112** may make a decision based on data received at the inputs **120a-120n**, the input **122**, the input **126** and/or other input. For example other inputs may comprise external signals generated in response to user input, external signals generated by the vehicle **50** and/or internally generated signals such as signals generated by the processor **112** in response to analysis of the signals FRAMES\_A-FRAMES\_N and/or objects detected in the signals FRAMES\_A-FRAMES\_N. The processor **112** may adjust the video data (e.g., crop, digitally move, physically move the camera sensor **130**, etc.) of the signals FRAMES\_A-FRAMES\_N.

The video analytics performed by the processor **112** may comprise analyzing, understanding and/or interpreting digital video to produce numerical and/or symbolic information about the digital video. The numerical and/or symbolic information may be used for interpreting visual information of the digital video. In an example, the intelligent video analytics may comprise computer vision.

In some embodiments, the processor **112** may be configured to extract data (e.g., the numerical and/or symbolic information) from the video frames. The extracted data may be used to determine the visual content of the video frames. Determining the visual content may comprise recognizing objects. In one example, the processor **112** may interpret the numerical and/or symbolic information to recognize that the visual data represents a vehicle. In some embodiments, the number of pixels and/or the colors of the pixels of the video data may be used to recognize portions of the video data as objects. The types of objects recognized by the processor **112** may be varied according to the design criteria of a particular implementation.

The processor **112** may generate a signal (e.g., CTRL) in response data received by the inputs **120a-120n**, the input **122** and/or the input **126** and/or the decisions made in response to the data received by the inputs **120a-120n**, the input **122** and/or the input **126**. The signal CTRL may be generated in response to the video analytics performed by the processor **112**.

The signal CTRL may be generated to provide a control signal for the interface **116** in response to the captured video frames (e.g., the signal FRAMES\_A-FRAMES\_N) and the video analytics performed by the processor **112**. For example, the video analytics may be performed by the processor **112** in real-time and/or near real-time (e.g., with minimal delay). For example, the output video may be a live (or nearly live) video stream.

The processor **112** may receive a signal (e.g., STATE) from the interface **116** at the input **126**. The signal STATE may comprise information corresponding to state data of the vehicle **50**. In an example, the state data of the vehicle **50** may comprise speed, tire pressure, whether the tail lights **62a-62n** are functional, brake fluid pressure, etc. The information in the signal STATE may be presented to the memory **114** with the signal DATA.

Generally, the video data presented to the memory **114** as the signal DATA may correspond to the data received at the inputs **120a-120n**, the input **122**, the input **126** and/or



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enhanced (e.g., stabilized, corrected, cropped, downscaled, packetized, compressed, etc.) by the processor 112. For example, the signal DATA may comprise video data that may be stitched, corrected, stabilized, cropped and/or encoded version of the signals FRAMES\_A-FRAMES\_N. The processor 112 may further encode and/or compress the signals FRAMES\_A-FRAMES\_N to generate the signal DATA.

The lenses 60a-60n (e.g., camera lenses) may be directed to provide a view from the perspective of the vehicle 50. The lenses 60a-60n may be aimed to capture environmental data (e.g., light). The lens 60a-60n may be configured to capture and/or focus the light for the capture devices 110a-110n. Generally, the camera sensor 130 is located behind each of the lenses 60a-60n. Based on the captured light from the lenses 60a-60n, the capture devices 110a-110n may generate a bitstream and/or video data.

Embodiments of the apparatus 100 may perform video stitching operations on the signals FRAMES\_A-FRAMES\_N. In one example, each of the video signals FRAMES\_A-FRAMES\_N may provide a portion of a panoramic view and the processor 112 may crop, blend, synchronize and/or align the signals FRAMES\_A-FRAMES\_N to generate the panoramic video signal. In some embodiments, the processor 112 may be configured to perform electronic image stabilization (EIS). The processor 112 may perform de-warping on the signals FRAMES\_A-FRAMES\_N. The processor 112 may perform intelligent video analytics on the de-warped video frames FRAMES\_A-FRAMES\_N. The processor 112 may encode the signals FRAMES\_A-FRAMES\_N to a particular format.

The encoded video may be stored locally and/or transmitted wirelessly to external storage (e.g., network attached storage, cloud storage, etc.). In an example, the encoded video may be stored locally by the memory 114. In another example, the encoded video may be stored to a hard-drive of a networked computing device. In yet another example, the encoded video may be transmitted wirelessly without storage. The type of storage implemented may be varied according to the design criteria of a particular implementation.

The cropping, downscaling, blending, stabilization, packetization, encoding, compression and/or conversion performed by the processor 112 may be varied according to the design criteria of a particular implementation. For example, the signal DATA may comprise a processed version of the signals FRAMES\_A-FRAMES\_N configured to fit the target area to the shape and/or specifications of the display device 58 and/or associated metadata. For example, the display device 58 may be implemented for real-time video streaming of the video data of the signal DATA received from the apparatus 100.

Generally, the signal DATA may comprise some view (or derivative of some view) captured by the capture devices 110a-110n. In some embodiments, the signal DATA may comprise a portion of a panoramic video captured by the capture devices 110a-110n. The signal DATA may be a video frame comprising the region of interest selected and/or cropped from a panoramic video frame by the processor 112. The signal DATA may have a smaller size than the panoramic video frames FRAMES\_A-FRAMES\_N. In some embodiments, the signal DATA may provide a series of cropped and/or enhanced panoramic video frames that improves upon the view captured by the lenses 60a-60n (e.g., provides night vision, provides High Dynamic Range (HDR) imaging, provides more viewing area, highlights detected objects, provides additional data such as a numerical distance to detected objects, provides visual indicators

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for expected paths, etc.). The video frames and/or the associated metadata stored in the memory 114 may be output by the apparatus 100 as the signal EVENT\_DATA.

The memory 114 may store data. The memory 114 may be implemented as a cache, flash memory, DRAM memory, etc. The type and/or size of the memory 114 may be varied according to the design criteria of a particular implementation. The data stored in the memory 114 may correspond to a video file, status information (e.g., readings from the components of the vehicle 50, pre-selected fields of view, user preferences, user inputs, etc.) and/or metadata information.

The interface 116 may send and/or receive data to/from the apparatus 100. In some embodiments, the interface 116 may be implemented as a wireless communications module. In one example, the interface 116 may be a hard-wired data port (e.g., a USB port, a mini-USB port, a USB-C connector, HDMI port, an Ethernet port, a DisplayPort interface, a Lightning port, etc.). In another example, the interface 116 may be a wireless data interface (e.g., Wi-Fi, Bluetooth, ZigBee, cellular, etc.).

The interface 116 may be configured to receive the signal CTRL from the processor 112. The interface 116 may present one or more of the signals SEN\_A-SEN\_N to one or more components of the vehicle 50 (e.g., the tail lights 62s-62c, the display device 58, the audio output device 54, etc.). The interface 116 may convert the signal CTRL, generated by the processor 112, to a format compatible with the various components of the vehicle 50.

The interface 116 may be configured to receive one or more of the signals SEN\_A-SEN\_N. The signals SEN\_A-SEN\_N may be received from the various components of the vehicle 50. The signals SEN\_A-SEN\_N may comprise state data of the vehicle 50. The interface 116 may present the signal STATE to the processor 112 in response to the state data.

The processor 112 may generate the signal CTRL, in response to the video analytics performed by the processor 112 on the video frames (e.g., the signals FRAMES\_A-FRAMES\_N). The processor 112 may determine an appropriate response. In one example, if the video analytics do not detect a collision hazard, the appropriate response may be to do nothing (e.g., the processor 112 may not generate the signal CTRL). In another example, if the video analytics do detect a collision hazard, the appropriate response may be determined based on factors detected by the video analytics. For example, the expected path (e.g., speed and/or acceleration) of the approaching vehicle 84a may be a factor.

The appropriate response determined by the processor 112 may be provided to the interface 116 in the signal CTRL. In one example, the appropriate response may be to activate the tail lights 62a-62n. In another example, the appropriate response may be to sound an alert using the audio output device 54. The interface 116 may be configured to convert the appropriate response from the signal CTRL to a format compatible with the various components of the vehicle 50. In one example, the signal SEN\_A may be presented to the tail lights 62a-62n and the data in the signal SEN\_A may be configured to blink the tail lights 62a-62n at a particular intensity and/or frequency. In another example, the signal SEN\_B may be presented to the audio output device 54 and the data in the signal SEN\_B may be configured to activate a particular tone from the audio output device 54. In yet another example, the signal SEN\_C may be connected to the display device 58, and the data in the signal SEN\_C may be configured to display the warning on the display device 58. The connections to various components by the signals



SEN\_A-SEN\_N and/or the data carried by the signals SEN\_A-SEN\_N may be varied according to the design criteria of a particular implementation.

In some embodiments, the apparatus 100 may be implemented as part of a larger system that collects traffic and/or safety data. For example, many vehicles may be equipped with the apparatus 100 in order to generate a large data set. The apparatus 100 may be configured to communicate data wirelessly or otherwise. In one example, the apparatus 100 may be configured to communicate wirelessly. In another example, the apparatus 100 may provide output from the memory 114 (e.g., a wired connection). The wired output from the apparatus 100 may be communicated using the communication device 142 implemented by the vehicle 50 (e.g., Wi-Fi, satellite communication, Bluetooth, 3G, 4G/LTE, 5G, etc.).

The apparatus 100 may generate information about a detected event and/or the severity of the event (e.g., the signal EVENT\_DATA). For example, the event may be a collision and/or a near miss. The information about the detected event (e.g., the signal EVENT\_DATA) may comprise the video data generated by the processor 112 from the signals FRAMES\_A-FRAMES\_N. The information about the detected event (e.g., the signal EVENT\_DATA) may comprise metadata such as a location, a time-of-day, detected weather conditions, speed of the vehicles, acceleration of the vehicles, etc. The information about the detected event (e.g., the signal EVENT\_DATA) may comprise the state data from the vehicle 50 (e.g., information in the signal STATE).

The signal EVENT\_DATA may be presented to the black box recorder 140 and/or the communication device 142. In an example, the signal EVENT\_DATA may be stored by the black box recorder 140 and may be recovered at the scene of an accident (e.g., for police investigation and/or insurance claims investigation). The data stored in the black box recorder 140 may be recovered in a scenario where the vehicle 50 and/or the communication device 142 is destroyed before transmission of the signal EVENT\_DATA could occur. The information recorded by the black box recorder 140 and/or communicated by the communication device 142 may be used by police to determine fault and/or provide more detail about the event (e.g., collision) in an event post mortem. The signal EVENT\_DATA may be communicated (e.g., uploaded) to a central database. Statistical analysis may be performed on the aggregated data from the events. The statistical analysis may be used to evaluate road safety. For example, the events may be used by civil and/or highway engineers to make safety improvements based on information in the signal EVENT\_DATA.

Referring to FIG. 4, a diagram illustrating an example video frame 150 analyzed using video analytics is shown. The video frame 150 may be one of the video frames FRAMES\_A-FRAMES\_N. In an example, the video frame 150 may be an example of video data captured within the field of view 74a-74b of one of the lenses 60a-60n. In the example shown, the video frame 150 may be a view from the perspective of the rear of the vehicle 50 (e.g., capturing a view looking behind the vehicle 50). The video frame 150 may be a representation of visual data captured by the sensor 130a and/or analyzed by the processor 112.

The video frame 150 may capture a section of the lane 80a and/or a section of the lane 80b. The video data captured in the video frame 150 may comprise the approaching vehicle 84a. The video data captured in the video frame 150 may comprise the vehicle 84b.

The processor 112 may be configured to perform video analytics on the visual data in the video frame 150. The video analytics may be configured to detect the vehicle 84a and/or the vehicle 84b as objects. A box 152a is shown around the vehicle 84a. A box 152b is shown around the vehicle 84b. The box 152a may represent the processor 112 identifying the vehicle 84a as an object in the visual data of the video frame 150. The box 152b may represent the processor 112 identifying the vehicle 84b as an object in the visual data of the video frame 150. In the example shown, objects 152a-152b are shown. However, other objects (e.g., vehicles, pedestrians, animals, obstacles, obstructions, etc.) may be identified by the processor 112 (e.g., objects 152a-152n). The method for identifying the vehicles 84a-84b as objects in the visual data of the video frame 150 may be varied according to the design criteria of a particular implementation.

The video analytics performed by the processor 112 may be performed on more than one video frame. For example, the video frame 150 may be one video frame of a series (or sequence) of video frames analyzed by the processor 112. The video analytics may be performed on video frames captured temporally before and/or after the video frame 150. By performing the video analytics on many video frames (or portions of each of the many video frames), the processor 112 may determine an expected path of the detected objects 152a-152n.

In the video frame 150, an arrow 154a is shown pointing to the object 152a. Similarly, an arrow 154b is shown pointing to the object 152b. The arrow 154a may represent a previous path of the object 152a (e.g., determined using video analytics on video frames captured prior to the video frame 150). The arrow 154b may represent a previous path of the object 152b (determined using video analytics on video frames captured prior to the video frame 150). The previous paths 154a-154b may be used by the processor 112 to determine a current speed, direction and/or acceleration of the objects 152a-152b. The current speed, direction and/or acceleration of the objects 152a-152b may be used by the processor 112 to determine an expected path of the objects 152a-152b.

In the video frame 150, an arrow 156a is shown pointing away from the object 152a. Similarly, an arrow 156b is shown pointing away from the object 152b. The arrow 156a may represent an expected path of the object 152a determined by the processor 112 based on the video analytics. The arrow 156b may represent an expected path of the object 152b determined by the processor 112 based on the video analytics. The expected paths 156a-156b may be calculated by the processor 112 to determine a potential future speed, direction and/or acceleration of the objects 152a-152b. The potential future speed, direction and/or acceleration of the objects 152a-152b may be used by the processor 112 to determine whether one or more of the objects 152a-152b may pose a collision hazard with the vehicle 50.

In some embodiments, the video frame 150 may be used as a proxy to represent the location of the vehicle 50 with respect to the objects 152a-152b. Generally, the lenses 60a-60n may be attached to the vehicle 50 and if an object is determined to pose a collision hazard with one or more of the lenses 60a-60n, the object may collide with the vehicle 50. For example, if an object is approaching the video frame (e.g., getting larger in the video frame as time passes), the object may pose a collision hazard with the vehicle 50.

The expected path 156b is shown directed away from the perspective of the video frame 150. For example, the vehicle 84b may be in the oncoming lane 80b traveling away from



the vehicle **50**. In subsequent video frames, the object **152b** may become smaller as the object **152b** travels away from the capture location of the video frame **150**. In the example shown, the expected path **156b** may not pose a collision hazard with the vehicle **50**. In an example with no collision hazard, the processor **112** may not generate the control signal to generate the warning.

The expected path **156a** is shown directed towards the perspective of the video frame **150**. For example, the vehicle **84a** may be in the same lane **80a** as the vehicle **50** and/or traveling approaching the vehicle **50**. In subsequent video frames, the object **152a** may become larger as the object **152a** travels closer to the capture location of the video frame **150**. In the example shown, the expected path **156a** may pose a collision hazard with the vehicle **50**. In an example with a potential collision hazard, the processor **112** may generate the control signal to generate the warning.

In some embodiments, the processor **112** may be configured to provide directional data from the expected path **156a-156b**. For example, the control signal CTRL may be generated in response to the directional data determined using the video analytics. The directional data may be used to generate an appropriate warning. In an example, the warning lights **64a-64n** may be directed towards the incoming vehicle (e.g., the vehicle **84a** and/or the vehicle **84n**) that poses the collision hazard. In another example, directional audio may be implemented using the audio output device **54**. Using the directional data determined by the video analytics, the processor **112** may present the signal CTRL to enable the audio output device **54** to provide directional audio as the warning. The directional audio may be implemented to prevent and/or reduce the risk of distracting other drivers in the vicinity. For example, a general audio warning may cause vehicles that do not pose a collision hazard to take evasive actions (e.g., that could unintentionally cause a collision with vehicles and/or pedestrians). A directed warning may be used to reduce a likelihood that vehicles that do not pose a collision hazard may react to the warning.

Referring to FIG. **5**, a method (or process) **200** is shown. The method **200** may generate a control signal in response to a detected object posing a collision hazard. The method **200** generally comprises a step (or state) **202**, a step (or state) **204**, a step (or state) **206**, a step (or state) **208**, a decision step (or state) **210**, a step (or state) **212**, a decision step (or state) **214**, a step (or state) **216**, a step (or state) **218**, and a step (or state) **220**.

The state **202** may start the method **200**. In the state **204**, the lenses **60a-60n** and/or the capture devices **110a-110n** may capture the video frames FRAMES\_A-FRAMES\_N. The processor **112** may receive the signals FRAMES\_A-FRAMES\_N at the inputs **120a-120n**. Next, in the state **206**, the processor **112** may generate video data from the video frames. The video data may be used internally by the processor **112**. In some embodiments, the video data may be presented to the display **58** and/or to the memory **114** as part of the signal DATA. In the state **208**, the processor **112** may perform the video analytics on the video frames and/or the video data. Next, the method **200** may move to the decision state **210**.

In the decision state **210**, the processor **112** may determine whether an object (e.g., one or more of the objects **152a-152n**) has been detected in the video frame (e.g., the video frame **150**). If an object has not been detected, the method **200** may return to the state **204**. If an object has been detected, the method **200** may move to the state **212**. In the state **212**, the processor **112** may determine the expected path of the object. For example, the processor **112** may

determine the expected path **156a** for the detected object **152a** in the video frame **150** based on the video data in the signals FRAMES\_A-FRAMES\_N, the previous path **154a** and/or a speed (or acceleration) of the vehicle **84a**. Next, the method **200** may move to the decision state **214**.

In the decision state **214**, the processor **112** may determine whether the detected object poses a collision hazard. For example, the processor **112** may determine that the object **152a** in the video frame **150** poses a collision hazard with the vehicle **50** based on the expected path **156a**. If the object does not pose a collision hazard, the method **200** may return to the state **204**. If the object does pose a collision hazard, the method **200** may move to the state **216**. In the state **216**, the processor **112** may determine the appropriate warning (e.g., the appropriate response). For example, the appropriate response may be to flicker the tail lights **62a-62n** of the vehicle **50** to warn the driver piloting the approaching vehicle **84a**. Next, in the state **218**, the processor **112** may generate the control signal CTRL. The signal CTRL may be presented to the interface **116**. Based on the signal CTRL, the interface **116** may generate one or more of the signals SEN\_A-SEN\_N to enable the appropriate warning. In an example, the signal SEN\_I may be generated to flicker the tail lights **62a-62n**. Next, the method **200** may move to the state **220**. The state **220** may end the method **200**.

Referring to FIG. **6**, a method (or process) **250** is shown. The method **250** may implement multiple warning types. The method **250** generally comprises a step (or state) **252**, a step (or state) **254**, a decision step (or state) **256**, a step (or state) **258**, a step (or state) **260**, a step (or state) **262**, a decision step (or state) **264**, a step (or state) **266**, and a step (or state) **268**.

The state **252** may start the method **250**. In the state **254**, the processor **112** may determine the expected path of the detected object. For example, the processor **112** may determine the expected path **156a** for the detected object **152a** in the video frame **150** based on the video data in the signals FRAMES\_A-FRAMES\_N, the previous path **154a** and/or a speed (or acceleration) of the vehicle **84a**. Next, the method **250** may move to the decision state **256**. In the decision state **256**, the processor **112** may determine whether the detected object poses a collision hazard. For example, the processor **112** may determine that the object **152a** in the video frame **150** poses a collision hazard with the vehicle **50** based on the expected path **156a**. If the object does not pose a collision hazard, the method **250** may move to the state **268**. If the object does pose a collision hazard, the method **250** may move to the state **258**.

In the state **258**, the processor **112** may determine the appropriate warning (e.g., the appropriate response). The appropriate response may be a first response (e.g., an initial warning). For example, the first response may be to flicker the tail lights **62a-62n** of the vehicle **50** to warn the driver piloting the approaching vehicle **84a**. Using a first response may be less intrusive and/or distracting to other drivers (e.g., to the vehicles **84b-84n**) while still providing enough of a warning to the vehicle **84a** to avoid the potential collision. Next, in the state **260**, the processor **112** may generate the control signal CTRL. The signal CTRL may be presented to the interface **116**. Based on the signal CTRL, the interface **116** may generate one or more of the signals SEN\_A-SEN\_N to enable the initial warning. In an example, the signal SEN\_I may be generated to flicker the tail lights **62a-62n**. Next, the method **250** may move to the decision state **262**.

In the state **262**, the processor **112** may perform video analytics on the video data to update the expected path. For



example, processor 112 may perform video analytics on frames after the video frame 150 to determine an update to the expected path 156a (e.g., determine whether or not the detected object 152a has an altered path in response to the previous warning). Next, the method 250 may move to the decision state 264. In the decision state 264, the processor 112 may determine whether the object is still a collision hazard (e.g., based on the updated expected path). If the object is still a collision hazard, the method 250 may move to the state 266. In the state 266, the processor 112 may determine a next warning.

The next warning (or response) may be determined based on a response of the detected object to the previous warning and/or the urgency of the potential collision hazard. In an example, if the previous warning was flickering the tail lights 62a-62n, the next warning may be playing loud audio using the audio output device 54. In another example, if the urgency of the collision hazard is high (e.g., a collision is imminent), the next response may be to initiate an evasive action by the vehicle 50. The next response (or warning) may be generated in response to the signals SEN\_A-SEN\_N. The signals SEN\_A-SEN\_N may be generated in response to the signal CTRL received by the interface 116 from the processor 112.

In the decision state 264, if the object is not still a collision hazard, the method 250 may move to the state 268. For example, if the approaching vehicle 84a has altered the expected path 156a in response to the previous warning, the detected object 152a may no longer be a collision hazard. No additional warnings may be needed. The state 268 may end the method 250.

Referring to FIG. 7, a method (or process) 300 is shown. The method 300 may activate safety measures in response to an imminent collision. The method 300 generally comprises a step (or state) 302, a step (or state) 304, a decision step (or state) 306, a decision step (or state) 308, a step (or state) 310, a step (or state) 312, a step (or state) 314, and a step (or state) 316.

The state 302 may start the method 300. In the state 304, the processor 112 may determine the expected path of the detected object. For example, the processor 112 may determine the expected path 156a for the detected object 152a in the video frame 150 based on the video data in the signals FRAMES\_A-FRAMES\_N, the previous path 154a and/or a speed (or acceleration) of the vehicle 84a. Next, the method 300 may move to the decision state 306. In the decision state 306, the processor 112 may determine whether the detected object poses a collision hazard. For example, the processor 112 may determine that the object 152a in the video frame 150 poses a collision hazard with the vehicle 50 based on the expected path 156a. If the object does not pose a collision hazard, the method 300 may move to the state 316. If the object does pose a collision hazard, the method 300 may move to the decision state 308.

In the decision state 308, the processor 112 may determine whether a collision is imminent. For example, the processor 112 may perform the video analytics on the video frame 150 to determine the expected path 156a of the vehicle 84a. The expected path 156a may indicate that a crash with the vehicle 50 is unavoidable. For example, the vehicle 84a may be approaching the lens 60a at a high rate and/or the detected object 152a may appear large in the video frame 150 to indicate a collision. If the collision is not imminent, the method 300 may move to the state 310. In the state 310, the processor 112 may determine the appropriate warning. For example, for an expected path that does not indicate an imminent collision, the appropriate warning may be to

flicker the tail lights 62a-62n. Next, the method 300 may move to the state 314. In the decision state 308, if the collision is imminent, the method 300 may move to the state 312. In the state 312, the processor 112 may select the onboard safety device 56 to protect the driver 68. For example, the onboard safety device 56 may be a seatbelt restraint system. Next, the method 300 may move to the state 314.

In the state 314, the processor 112 may generate the control signal CTRL. Next, the method 300 may move to the state 316. The state 316 may end the method 300.

Referring to FIG. 8, a method (or process) 350 is shown. The method 350 may collect and communicate safety data using video analytics. The method 350 generally comprises a step (or state) 352, a step (or state) 354, a step (or state) 356, a step (or state) 358, a step (or state) 360, a step (or state) 362, a decision step (or state) 364, a step (or state) 366, a decision step (or state) 368, a step (or state) 370, and a step (or state) 372.

The state 352 may start the method 350. In the state 354, the processor 112 may generate video data from the video frames FRAMES\_A-FRAMES\_N. Next, in the state 356, the processor 112 may store the video data in the memory 114. For example, the video data may be transmitted as the signal DATA. In the state 358, the processor 112 may perform video analytics on the video frames FRAMES\_A-FRAMES\_N and/or the video data. In some embodiments, the video analytics may be performed as the video frames FRAMES\_A-FRAMES\_N are received. In some embodiments, the video data may be retrieved from the memory 114 by the processor 112. Next, in the state 360, the processor 112 may collect the vehicle state information. For example, the processor 112 may receive the signal STATE from the interface 116. The interface 116 may receive information from various components of the vehicle 50 from the signals SEN\_A-SEN\_N. In the state 362, the processor 112 may store metadata associated with the video in the memory 114. For example, the metadata may comprise location information, speed information, a timestamp, a vehicle identification number, a serial number for the camera, etc. The metadata may further comprise the vehicle state information. The metadata may be transmitted to the memory 114 as the signal DATA (e.g., along with the video data). Next, the method 350 may move to the decision state 364.

In the decision state 364, the processor 112 may determine whether the video analysis has detected an event. The event may be a collision, a near collision and/or a particular scenario (e.g., parking, unloading cargo, traveling particular intersections, etc.). If an event has not been detected, the method 350 may return to the state 354. If an event has been detected, the method 350 may move to the state 366. In the state 366, the processor 112 and/or the memory 114 may flag the video and the metadata associated with the event for communication. Next, the method 350 may move to the decision state 368.

In the decision state 368, the apparatus 100 and/or the components of the vehicle 50 may determine whether to communicate the data. In some embodiments, the data may be communicated using the communication device 142 at particular times and/or time intervals. In some embodiments, the data may be communicated live (e.g., streamed as output as it is recorded). If the data is not to be communicated (e.g., the data is not flagged for communication), the method 350 may move to the state 372. If the data is to be communicated (e.g., the data is flagged for communication), the method 350 may move to the state 370. In the state 370, the memory 114 may send the flagged data to the black box recorder 140



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and/or the communication device 142 (e.g., as the signal EVENT\_DATA). Next, in the state 372, the memory 114 may delete the unflagged data (e.g., purge data to ensure the memory 114 has available storage for future events). Next, the method 350 may return to the state 354.

The functions and structures illustrated in the diagrams of FIGS. 1 to 8 may be designed, modeled, emulated, and/or simulated using one or more of a conventional general purpose processor, digital computer, microprocessor, micro-controller, distributed computer resources and/or similar computational machines, programmed according to the teachings of the present specification, as will be apparent to those skilled in the relevant art(s). Appropriate software, firmware, coding, routines, instructions, opcodes, micro-code, and/or program modules may readily be prepared by skilled programmers based on the teachings of the present disclosure, as will also be apparent to those skilled in the relevant art(s). The software is generally embodied in a medium or several media, for example non-transitory storage media, and may be executed by one or more of the processors sequentially or in parallel.

Embodiments of the present invention may also be implemented in one or more of ASICs (application specific integrated circuits), FPGAs (field programmable gate arrays), PLDs (programmable logic devices), CPLDs (complex programmable logic device), sea-of-gates, ASSPs (application specific standard products), and integrated circuits. The circuitry may be implemented based on one or more hardware description languages. Embodiments of the present invention may be utilized in connection with flash memory, nonvolatile memory, random access memory, read-only memory, magnetic disks, floppy disks, optical disks such as DVDs and DVD RAM, magneto-optical disks and/or distributed storage systems.

The terms “may” and “generally” when used herein in conjunction with “is(are)” and verbs are meant to communicate the intention that the description is exemplary and believed to be broad enough to encompass both the specific examples presented in the disclosure as well as alternative examples that could be derived based on the disclosure. The terms “may” and “generally” as used herein should not be construed to necessarily imply the desirability or possibility of omitting a corresponding element.

While the invention has been particularly shown and described with reference to embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made without departing from the scope of the invention.

The invention claimed is:

1. An apparatus comprising:

a sensor configured to capture video frames of an environment near a vehicle; and

a processor configured to (i) receive said video frames from said sensor, (ii) perform video analytics on said video frames and (iii) generate a control signal in response to said video analytics, wherein (a) said video analytics analyze visual content in said video frames to identify an object approaching said vehicle, (b) said video analytics determine (i) an expected path and (ii) an acceleration of said object approaching said vehicle, (c) said control signal is configured to generate a warning for said object approaching said vehicle if said expected path poses a collision hazard with said

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vehicle, and (d) said processor is configured to (i) perform said analytics on a plurality of said video frames to determine said expected path of said object, (ii) determine a plurality of said expected paths and (iii) said plurality of expected paths are used to determine said acceleration.

2. The apparatus according to claim 1, wherein said warning comprises generating a signal to blink a tail light system of said vehicle.

3. The apparatus according to claim 1, wherein said vehicle is at least one of (i) a slow-moving vehicle and (ii) a stationary vehicle.

4. The apparatus according to claim 1, wherein said warning comprises an audio output.

5. The apparatus according to claim 1, wherein (i) said warning is generated for a driver of said vehicle and (ii) said warning comprises a visual indication to said driver of said vehicle.

6. The apparatus according to claim 1, wherein said control signal is further configured to prepare a safety response of said vehicle.

7. The apparatus according to claim 1, wherein said expected path of said object determined by said video analytics comprises a rear end collision with said vehicle.

8. The apparatus according to claim 1, wherein determining said expected path comprises determining at least one of (i) said acceleration of said object and (ii) a speed of said object.

9. The apparatus according to claim 1, wherein said processor is configured to store data associated with said collision hazard.

10. The apparatus according to claim 9, wherein said apparatus is further configured to communicate said data associated with said collision hazard to an external service.

11. The apparatus according to claim 9, wherein said apparatus is further configured to communicate said data associated with said collision hazard to a black box recorder.

12. The apparatus according to claim 9, wherein said data associated with said collision hazard comprises said video frames and metadata.

13. The apparatus according to claim 9, wherein said data associated with said collision hazard comprises state information of said vehicle.

14. The apparatus according to claim 1, wherein (i) said object approaching said vehicle is a second vehicle and (ii) said second vehicle is approaching said vehicle from behind.

15. The apparatus according to claim 1, wherein said apparatus is configured to implement a rear collision alert system.

16. The apparatus according to claim 1, wherein said collision hazard detected in response to said expected path of said object determined by said video analytics comprises a side collision with said vehicle.

17. The apparatus according to claim 1, wherein (i) said expected path is used to determine a direction of said collision hazard and (ii) said warning is implemented towards said direction of said collision hazard.

18. The apparatus according to claim 17, wherein said warning implemented towards said direction of said collision hazard is implemented to reduce a risk of distracting vehicles that do not pose said collision hazard.

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